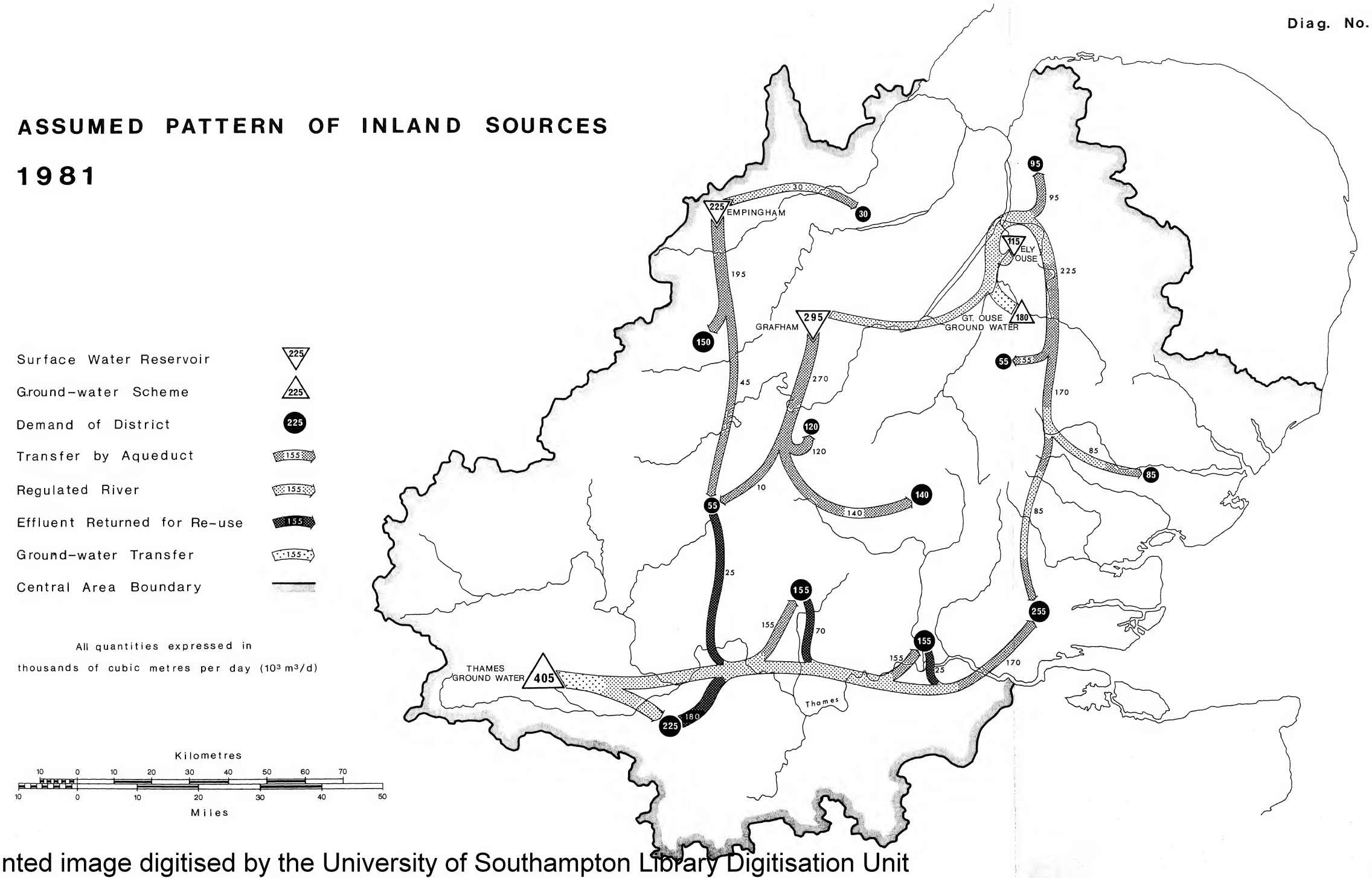
ASSUMED PATTERN OF INLAND SOURCES

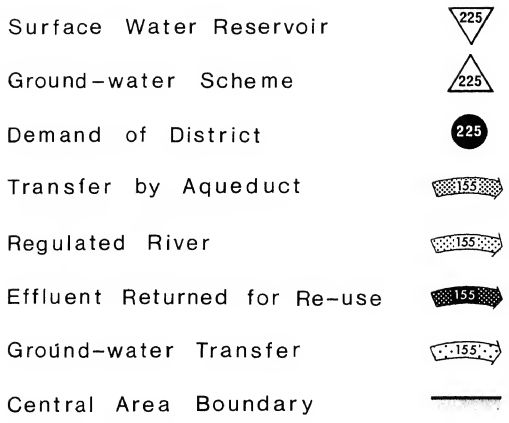
1981



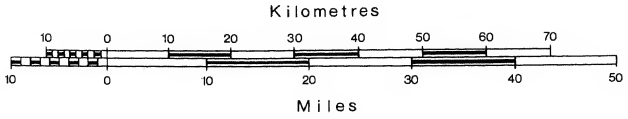
Programme 1

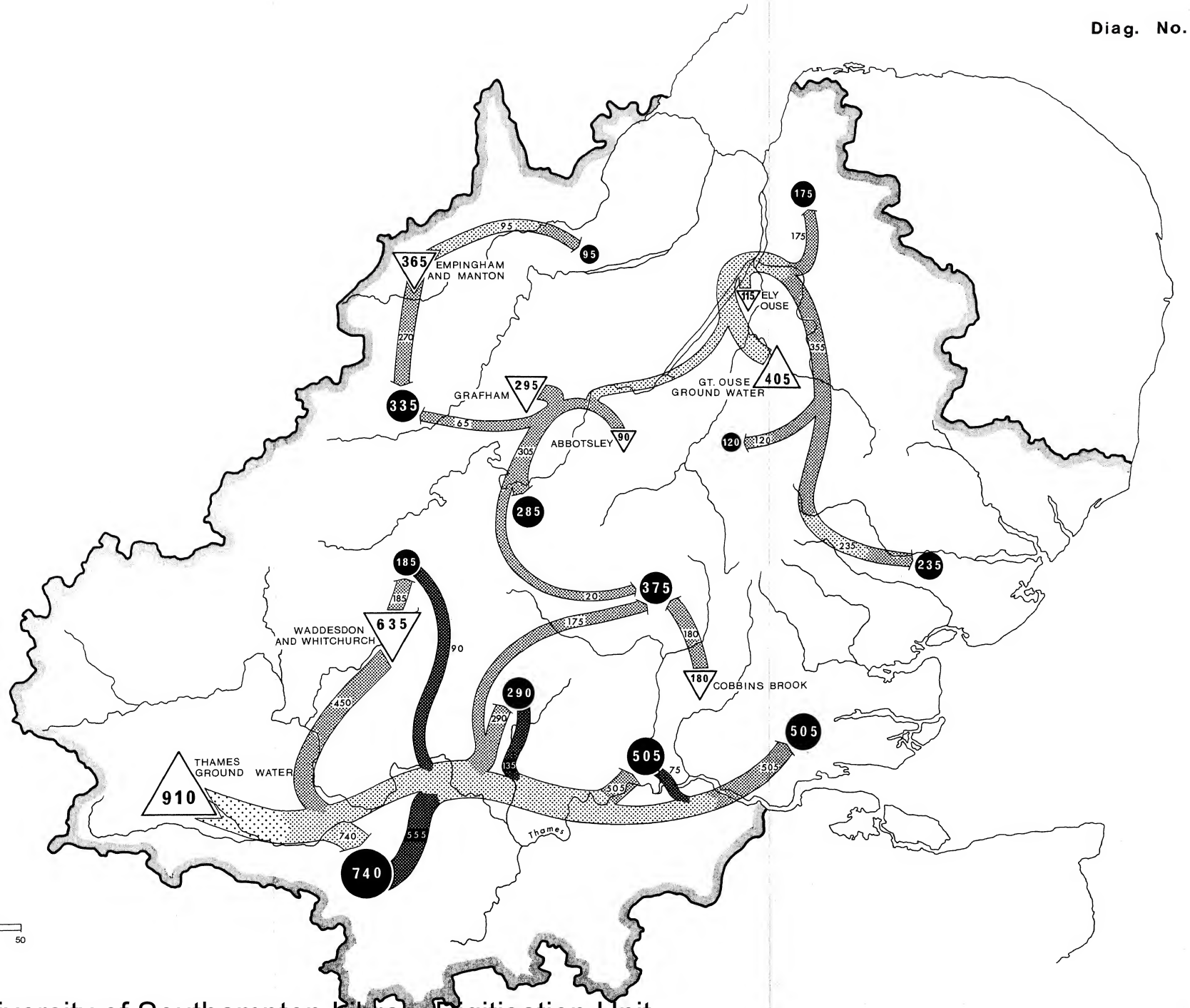
INLAND SOURCES

2001



All quantities expressed in thousands of cubic metres per day ($10^3 m^3/d$)

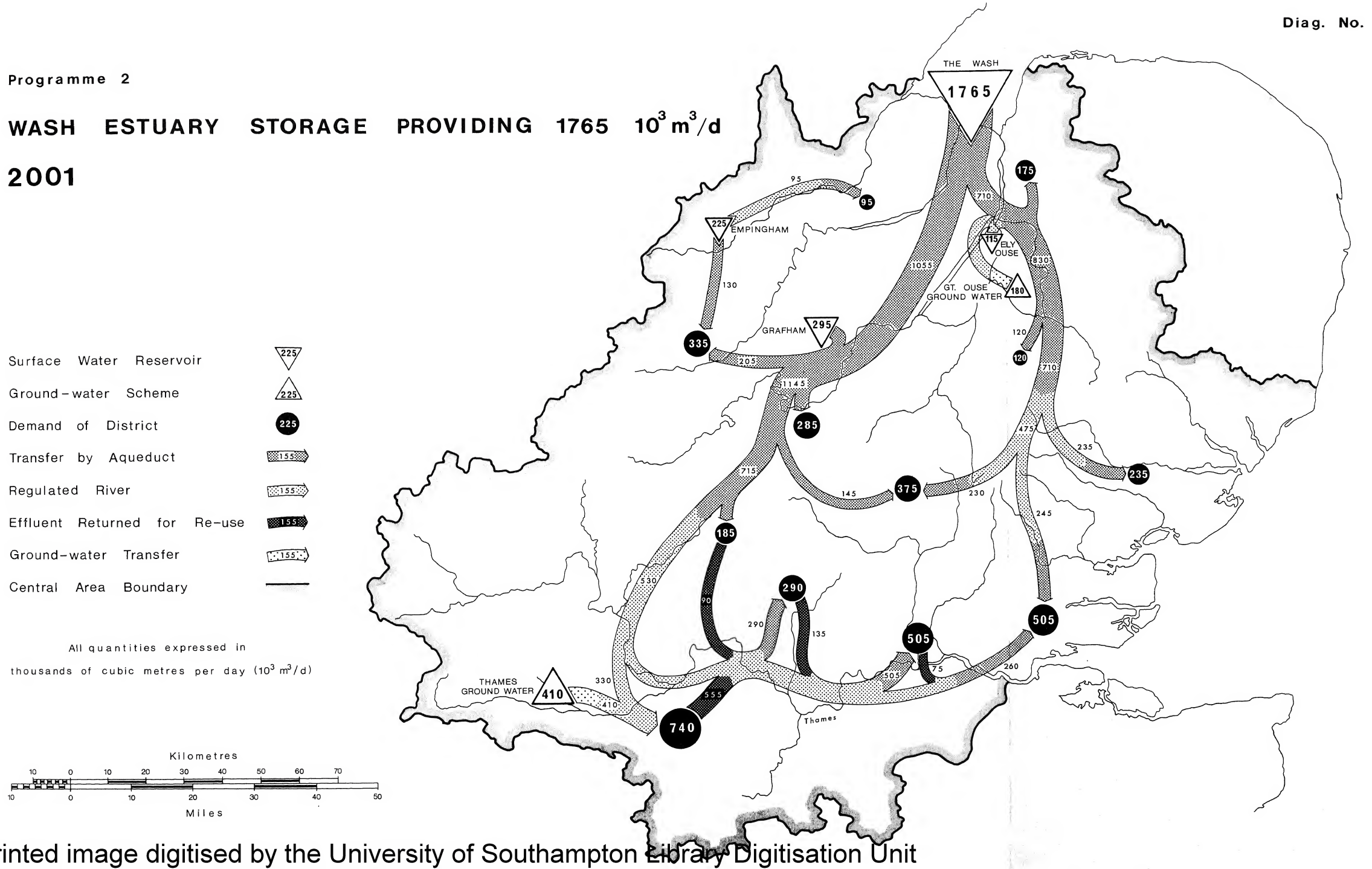




Programme 2

WASH ESTUARY STORAGE PROVIDING 1765 $10^3 m^3/d$

2001



Programme 3

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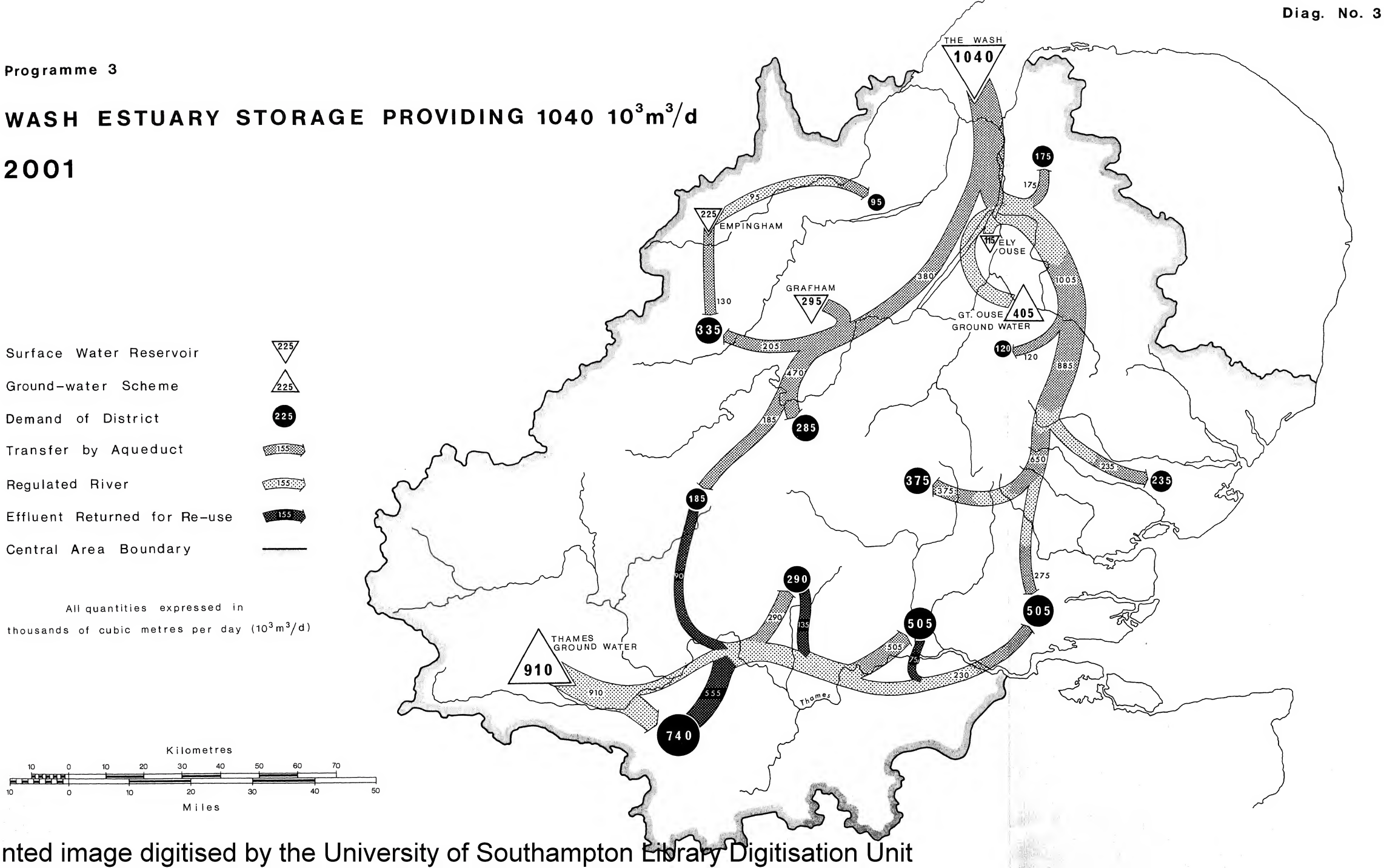
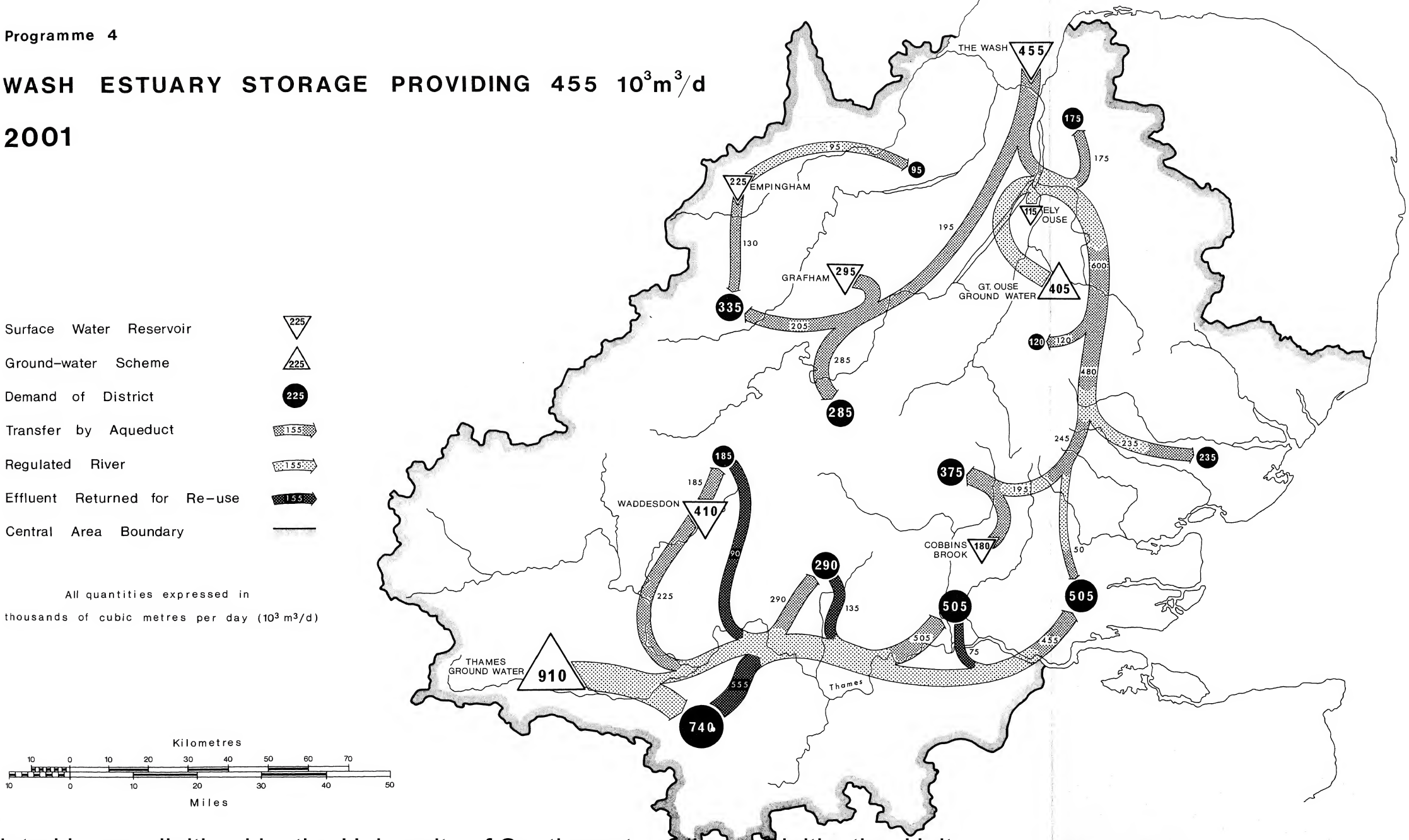
2001



Programme 4

WASH ESTUARY STORAGE PROVIDING 455 $10^3 m^3/d$

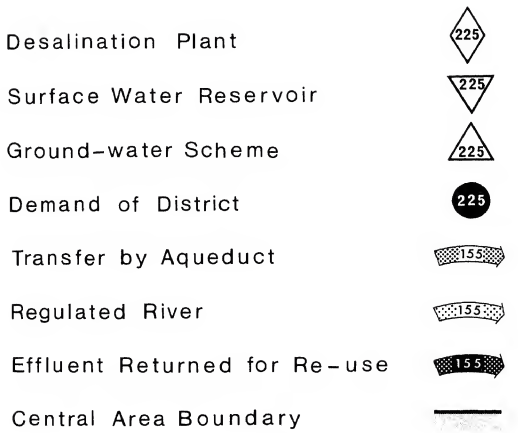
2001



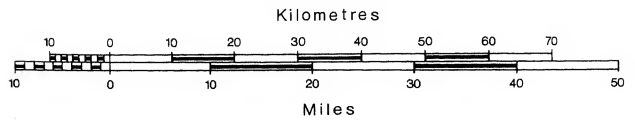
Programme 5

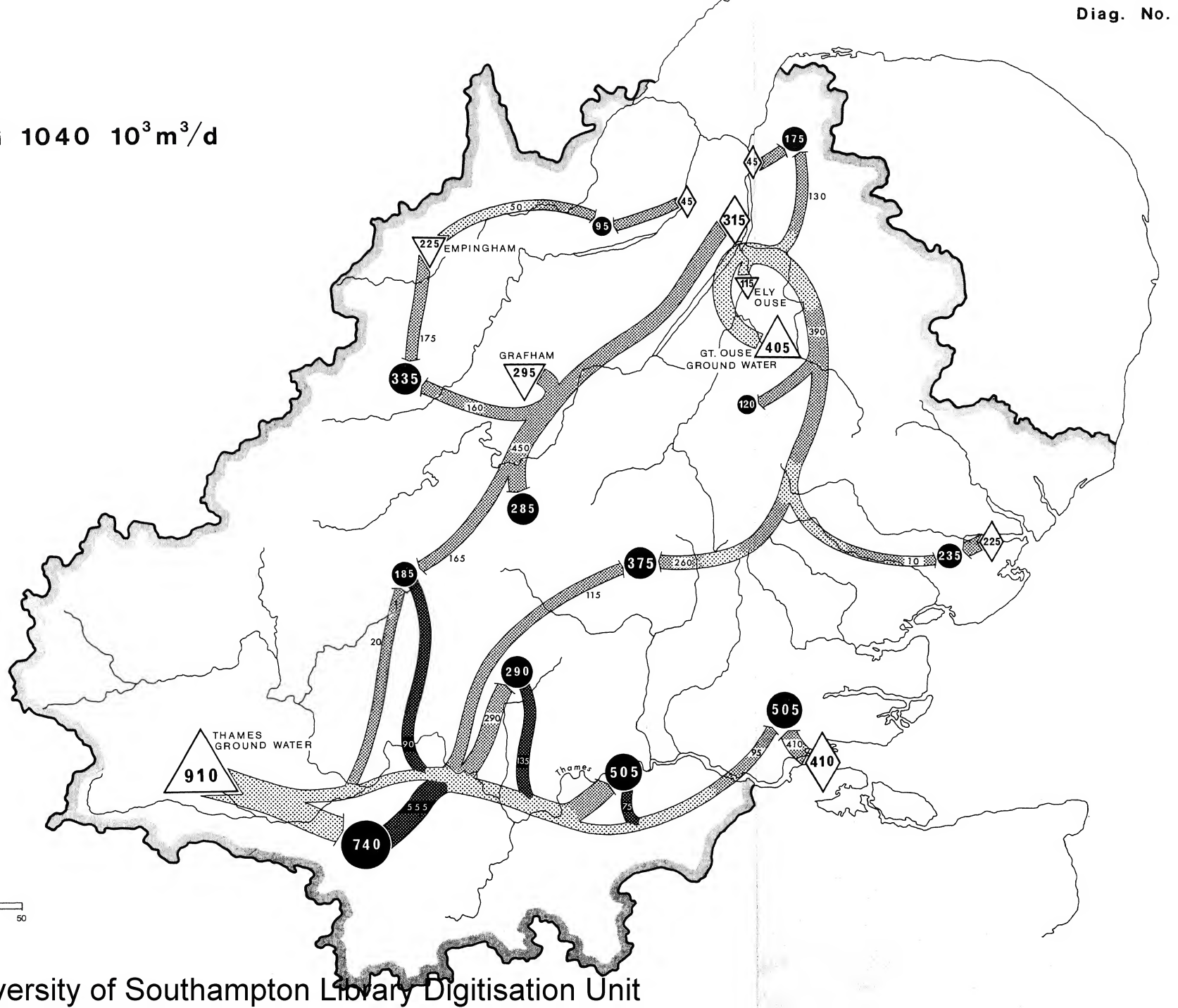
DESALINATION PROVIDING 1040 $10^3 m^3/d$

2001



All quantities expressed in thousands of cubic metres per day ($10^3 m^3/d$)





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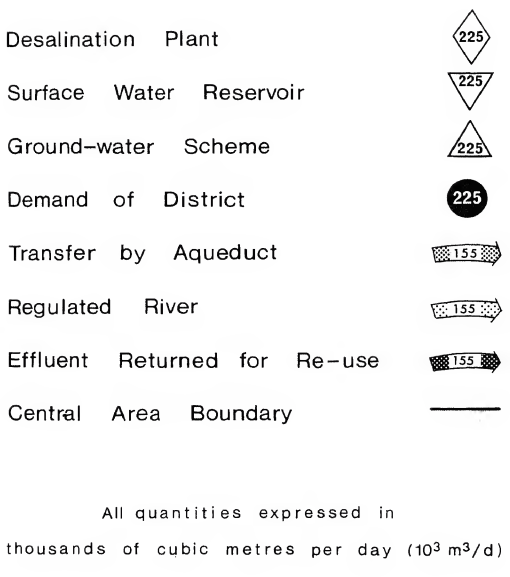
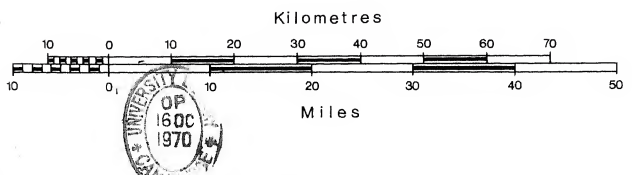
2001



All quantities expressed in thousands of cubic metres per day ($10^3 m^3/d$)



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MAP 1

WATER RESOURCES BOARD

THE WASH : ESTUARY STORAGE

Report on the Desk Study

PLAN OF SUGGESTED DEVELOPMENTS

Possible Site of Barrage

Intake

Training wall

Stage 4

Pumped storage reservoirs

Intake

Stage 3

Sea-water transfer intakes

Training wall

Stage 2

Stage 1

WATER RESOURCES BOARD

THE WASH : ESTUARY STORAGE

Report on the Desk Study

DEMAND DISTRICTS AND NOTIONAL DELIVERY POINTS

Demand District

Notional Delivery Point (in metres A.O.D.) — 122

Central Area Boundary

River Authority Boundary

Statutory Water Undertaking Boundary

River Authorities

5 WELLAND AND NENE R. A.

6 GREAT OUSE R. A.

7 EAST SUFFOLK AND NORFOLK R. A.

8 ESSEX R. A.

9 KENT R. A.

10 SUSSEX R. A.

11 HAMPSHIRE R. A.

12 ISLE OF WIGHT RIVER AND WATER AUTHORITY

13 AVON AND DORSET R. A.

28 THAMES C. A.

29 LEE C. A.

A LONDON EXCLUDED AREA

WATER RESOURCES BOARD

THE WASH: ESTUARY STORAGE
REPORT ON DESK STUDY

CORRECTIONS

Page 21:	Para 81: second line.	Amend "132 000 m^3/d" to "1 320 000 m^3/d"
Page 24:	Para 89: third line.	Amend "9 000 000 m^3/d" to "900 000 m^3/d"
Page 27:	Para 100: third line.	Amend "9 000 000 m^3/d" to "900 000 m^3/d"

LONDON: HER MAJESTY'S STATIONERY OFFICE

CHAPTER 1

INTRODUCTION

Background: the South East of England

1. In our Report on Water Supplies in South East England (HMSO 1966) we indicated a Central Area in which major new sources of water would be required to meet the forecast demands up to the end of this century. It comprises the areas of the Welland and Nene, Great Ouse and Essex River Authorities, the Thames Conservancy and the Lee Conservancy Catchment Board, and parts of those of the Kent River Authority (metropolitan Kent) and the East Suffolk and Norfolk River Authority (the Ipswich area). We estimated that the total deficiency in the Central Area at the year 2001 would be 2 950 000 cubic metres per day (m^3/d) (650 million gallons per day (mgd)).

2. The essence of our regional planning is to identify the options available and to secure their detailed physical investigation as a basis for firm decisions on a strategy of development. In our Report of 1966 we indicated that the deficiency in the Central Area might be met from the following sources: surface storage; estuary storage in the Wash; ground water; desalination; artificial recharge of aquifers; and imports from outside the area. Work on the last two has not reached the stage where their potential contribution can be properly assessed. The first four are thus the options for the Central Area which require physical investigation.

3. Of the seven reservoir sites we listed in 1966, one has been authorised for use; four have been investigated; two remain to be investigated. Proposals for surface reservoirs in the South East are subject to strong opposition from the various interests affected by them.

4. Two ground-water pilot schemes have been undertaken, one by the Great Ouse River Authority and one by the Thames Conservancy; and the Conservancy have announced their plans for further development. But it is not possible at this stage to say with certainty what the ultimate yield of the ground-water schemes will be.

5. Research and development work on desalination processes continue; and we have proposed, jointly with the UK Atomic Energy Authority, that an experimental plant should be constructed near Ipswich, using the secondary refrigerant

process. But the success of this process on a large scale is not yet proved; future costs of desalination processes generally cannot be forecast with certainty; and the strength of objection to large desalination plants on the coast cannot yet be gauged.

6. Three of the four options are thus under physical investigation; none of these is free from either objection or uncertainty. Physical investigation of the fourth option - estuary storage - remains to be undertaken.

The Wash

7. Our reference in our Report of 1966 to the possibility of fresh water storage in the Wash was based on information given in an earlier report prepared by Messrs Binnie and Partners for the Ministry of Housing and Local Government - "The Water Resources of the Great Ouse Basin" (1965) - which made a preliminary examination of a proposal for a barrage to cut off about half the area of the Wash so that fresh water from the rivers Great Ouse, Nene, Welland and Witham could be impounded behind the barrage and pumped into storage lagoons within the impounded area. That report assessed the possible yield at over 2 700 000 m^3/d (600 mgd) but estimated that studies to establish the feasibility of closure, control of water quality, maintenance of drainage and navigation, and other essential matters, would possibly take about five years and might cost £1.5 million.

8. We considered that these possibilities deserved to be examined in greater depth. We therefore recommended in our 1966 Report that a feasibility study* of the Wash should be undertaken at the same time as the investigations of inland sources. The Government did not authorise such a feasibility study, but in May 1968 authorised a desk study* at a cost of about £25,000. This desk study is the subject of this report.

The Desk Study

9. We instructed our Consulting Engineers, Messrs Binnie and Partners, in October 1968 in the following general terms:

> "The Consulting Engineers are required to investigate and report upon the scope for water conservation in the Wash insofar as this can

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* *'Feasibility study' and 'desk study'. In this Report 'feasibility study' means a full engineering and scientific study including fieldwork and laboratory work; 'desk study' means a primarily theoretical study excluding these.*

be done without extensive field and laboratory investigation, and to set out in detail the content and the estimated costs of a full feasibility study."

10. We were anxious to examine the possibilities of various forms of development not only as means of producing water but also more generally for their effect upon the whole environment of the area. We therefore included these aspects in our Consulting Engineers' detailed terms of reference and also sought the specialised views of the following bodies:

The Natural Environment Research Council
The Nature Conservancy
The Countryside Commission
The Ministry of Agriculture, Fisheries and Food
The Ministry of Transport
The East Anglia Economic Planning Council
The River Authorities
The Local Authorities in the area
The National Ports Council
The Sports Council

We have consulted representatives of these bodies on several occasions and are grateful for the co-operation they have given us and for the reports they have produced. We hope that they will find an adequate reflection of their views in our own Report.

11. Chapters 2 and 4 of this Report are based on the Consulting Engineers' Report. Chapter 3 is based on the specialised reports by the other bodies named above.

12. Copies of the Consulting Engineers' Report and of the other specialised reports are available for inspection at our offices at Reading Bridge House in Reading.

CHAPTER 2

FORM OF DEVELOPMENT

Alternative Forms of Storage

13. Proposals have been made from time to time to build barrages across the Wash and other estuaries so as to exclude the sea from a part or all of the area and to allow fresh water to collect by gravity behind the barrage. In Messrs Binnie and Partners' Report of 1965 on the Great Ouse Basin it was suggested that high level lagoons or bunded reservoirs* be retained against the inner face of a barrage across the Wash so as to provide additional - and in some ways more dependable - storage. Alternatively, such reservoirs could be built on the coastal fringe of the bay, ie just off the inner shore, within the area behind the barrage, or possibly without the need to construct the barrage at all. Water would be pumped into these reservoirs, either from the area behind the barrage or, if there were no barrage, from points on the rivers which flow into the bay.

14. These different types of development have different implications for water quality, the prospects of siltation of the bay, land drainage, navigation and ecological change. They may also involve very different ranges of cost. Any study must therefore seek to establish what form of development is likely to serve best, and what the location and sequence of developments should be.

Recommended Form of Development

15. The Consulting Engineers have considered barrages across the Wash on a number of lines. They have also considered reservoirs either adjoining the present sea defences or somewhat further out in the bay, and combinations of barrages and reservoirs.

16. They conclude that on virtually all counts the balance of advantage would lie with comparatively small bunded reservoirs on the fringes of the inter-tidal area. They envisage three or four such reservoirs just off the south west shore of the bay, as indicated on Map 1, between the outfall of the Great Ouse and that of the Welland, together with suitable training works to maintain the outfalls. It might prove necessary to extend these training works to combat siltation or conceivably, in the last resort, to provide an enclosing barrage. The reservoirs would cover in all an area of about 100 square kilometres (km^2) (say 25,000 acres), about 15% of the total area of the Wash, and would rise to

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* *A bunded reservoir is one completely enclosed by an artificial bank or 'bund'.*

a height of some 9 metres (30 feet) above sea level. They would start a mile or so to seaward of the present margin of reclaimed land; the intervening strip might be reclaimed for agriculture or possibly for recreational use. The reservoirs would be filled by tunnel or pipeline from points on the rivers just upstream of the ports, tidal sluices being constructed at these points. The river outfalls, which would remain open to the tide below these points, would be maintained with the help of training walls or dredging. But if it proved necessary to exclude the sea by a barrage, locked navigation canals would need to be constructed in parallel with the river outfalls in addition to locks through the barrage.

17. The Consulting Engineers conclude that to build a barrage enclosing more than about half the area of the bay, say north east of a line from Snettisham to Butterwick Low, would be beyond the limits of present engineering technology. This view is endorsed by the most eminent and experienced Dutch engineers, who have contributed a valuable Appendix to the Consulting Engineers' Report.

18. A scheme which would exclude the tide from extensive areas of the bay, but without the protection of a shore-to-shore barrage, would involve the possibility of siltation of the areas remaining open to the tide, which might obstruct land drainage and navigation. It is implicit in the recommendations of the Consulting Engineers that they consider that any such problems could be overcome by training works or dredging, or both, at costs considerably lower than those of constructing an enclosing barrage. Indeed, they consider that for a first bunded reservoir of about 7 km^2 (1,700 acres) west of the outfall of the Great Ouse, which they designate Stage I, such dangers would be negligible.

Water Quality

19. The Consulting Engineers consider that stored water derived from the rivers feeding the Wash would be amenable to conventional treatment processes, although difficulties are to be expected of the kind familiar with waters rich in nutrients. Storage equipped with some artificial mixing device, and preceded by continuous monitoring of input quality, would be a desirable preliminary to treatment.

20. Contamination by sea water would not be a serious problem with pumped storage reservoirs of the kind advocated, and flushing out of salt from the reservoir bed could probably be accomplished during the construction period.

21. On the other hand, the Consulting Engineers consider that water from gravity storage through which shipping passed would be unacceptable for public supply because of pollution hazards and intrusion of sea water through locks; shipping channels through such storage would have to be confined between embankments.

Scale and Cost of Development

22. The yield ultimately available from storage in the Wash would depend on the volume and form of the storage provided. Pumped storage lagoons would not produce as much yield as the equivalent volume of gravity storage because it would be uneconomic to provide enough pumping capacity to enable flood water to be stored.

23. The yield would also depend on the following factors: (i) the residual river flows required downstream of any abstraction points; (ii) the growth of water use within the tributary basins, which will increase dry-weather flows by adding effluent to them; (iii) the extent to which water is exported from these basins. Some inland pumped storage schemes are already in operation or being built, a scheme of ground-water development is under investigation in the Great Ouse area, and other pumped storage reservoirs have been proposed. To make allowance for the various possible permutations of development, and the consequent effects on proposals for the Wash, is therefore a complex task.

24. The safe yields of Wash reservoirs of various capacities, fed from various combinations of rivers and at dates between 1981 and 2001, are set out in the Consulting Engineers' Report (Drawing No. 10). The assessments made allow for various possible combinations of inland schemes.

25. As a generalisation, however, storage of about 200 000 000 cubic metres (m^3) (44,000 million gallons (mg)) fed from the Great Ouse, Nene, Welland, and Witham, would support a gross yield of about 1 100 000 m^3/d (240 mgd). To double this yield to 2 200 000 m^3/d (480 mgd) would involve increasing the storage to about 750 000 000 m^3 (165,000 mg). By the year 2001 new effluents would add approaching 200 000 m^3/d (44 mgd) to these yields.

26. Storage fed from the Great Ouse only would give yields between half and two-thirds of those produced by all four rivers; and for other combinations of rivers, including the Great Ouse, the yields would of course be intermediate.

27. The Consulting Engineers estimate the capital costs of developing these schemes to give yields of 2 000 000 m^3/d (440 mgd) or more - depending on the factors mentioned above - at about £140 million, including works to deliver raw water as far as Denver, some 32 km (20 miles) inland. A barrage enclosing half the bay would cost an additional £135 million, although if completed following Stage I of the reservoir works it would reduce by about £15 million the cost of subsequent stages. The estimated capital cost of £140 million for a scheme without a barrage is rather lower than the equivalent costs of the scheme which formed the basis of comparison with inland sources in our Report on the South East. The effects of this, when the delivery system for the Central Area is taken into account, are brought out in Chapter 5 of this Report.

Staging of Development

28. The Consulting Engineers have considered the staging of development to meet demands growing at rates between 25 000 m^3/d (5½ mgd) and 100 000 m^3/d (22 mgd) per year, and spreading over one, two or three decades of development, to give ultimate yields between 500 000 m^3/d (110 mgd) and 2 400 000 m^3/d (530 mgd).

29. They conclude that for optimum economy storage should be developed in two stages for ultimate yields over two decades of 500 000 m^3/d (110 mgd), in three stages for yields of 1 000 000 or 1 500 000 m^3/d (220 or 330 mgd), and in four stages for yields of 2 000 000 m^3/d (440 mgd) or more (assumed to grow at 100 000 m^3/d (22 mgd) per year).

30. For the higher rates of demand growth (above 75 000 m^3/d (16 mgd) per year) the stages would each have an optimum yield of some 500 000 m^3/d (110 mgd) and for the lower growth rates the earlier stages, at least, yields of about half this amount.

A Stage I Reservoir

31. The Consulting Engineers' outline plans indicate four units of storage development, starting with a Stage I unit of about 65 000 000 m^3 (14,000 mg) capacity, covering about 7 km^2 (1,700 acres) of foreshore to the west of the outfall of the Great Ouse, which is the largest of the tributary rivers. This unit would be served by a common inlet/outlet tunnel of 2.5 metres (100 ins) diameter, connected to the Great Ouse upstream of a new tidal sluice just above King's Lynn. This location might also enable the Great Ouse flood relief channel, and the tunnel now under construction, to be used to convey water

relatively cheaply southwards to Essex. Later stages would have separate inlet and outlet works and would tap the resources of the other tributary rivers as well as the Great Ouse.

32. The Consulting Engineers consider that the Stage I reservoir would yield 450 000 m^3/d (100 mgd), but this yield would mean that at times when normal flow in the Great Ouse was at, or below, the maximum rate of abstraction, there would be no residual fresh water flow downstream of the abstraction point. On the other hand, the yield would be halved (225 000 m^3/d (50 mgd)) if a residual fresh water flow requirement were imposed similar to that which restricts abstraction under existing schemes. These two rates of yield are close to those indicated in paragraph 30 for rapid and slow rates of yield development, respectively. The Consulting Engineers suggest that the higher yield may be attainable by substituting pumped sea water for the residual fresh water flow (see paras 33-34 below). They estimate the cost of Stage I at £23 million, or £25 million to include the sea water scheme.

Sea Water Scheme

33. Where a residual flow of fresh water is required at the mouth of a river, particularly if its main function is to dilute a polluting effluent or to maintain an outfall channel, it may be possible to substitute a pumped supply of sea water. In the present case the works required would consist of an intake and pumping station in the Great Ouse outfall channel beyond the Stage I reservoir, and 12 kilometres (7 miles) of tunnel of 2.5 metres (100 ins) diameter which could deliver sea water at the rate of 900 000 m^3/d (200 mgd) to the site of the new sluice above King's Lynn.

34. The adequacy of this sea water supply as a replacement for the residual fresh water flow would, of course, require discussion with the various interests concerned. It would also be relevant to other measures designed to maintain the outfall channels downstream of the proposed tidal sluices. Such a scheme might serve to augment the net yield of certain inland schemes, particularly the proposed ground-water scheme, even if no storage at all were provided in the Wash. But in that event it would cost considerably more than the estimate of £2 million required to add it to the works needed in the Wash for the suggested Stage I storage.

CHAPTER 3

EFFECTS ON THE ENVIRONMENT

35. In this chapter we attempt to present a consensus of the preliminary opinions and views of those Government Departments and agencies, local authorities and other bodies whose responsibilities or interests would be affected by any developments in the estuary.

Natural Environment

36. The Wash is a large inlet of the sea breaching the mid-Norfolk and Lincolnshire chalk wolds and flooding a basin gouged out of the softer deposits to the south west. Within an area of 600 km^2 (232 square miles) there are some very fine marine and brackish water habitats which provide food and shelter for many types of fauna. Birds, both residents and migrants, and seals are particular features.

37. The principal habitats comprise:-

	km^2	acres
Area permanently covered by the sea	290	72,000
Intertidal sands and mud flats	280	70,000
Salt marshes	41	10,000
Sand dunes	3	750
Shingle beach	1.6	400

The Wash contains about 10% of all the sand and silt flats in Britain; those between Freiston and Wainfleet are second in size only to Maplin Sands, Essex.

38. The Wash has become considerably more important for wildlife conservation in recent years because of the rapid progress in the reclamation of similar areas in Holland. The area between Gibraltar Point and Wrangle Flats is included in a recent catalogue* prepared by the Nature Conservancy of nineteen coastal sites of international significance, and also in a register† prepared by the International Union for the Conservation of Nature of wetlands of outstanding significance for nature conservation.

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* *Nature Conservancy (unpublished)*

† *International Union for the Conservation of Nature: Publications, New Series, No. 5. Project MAR, Vol. II, 1965*

39. The Wash is the most important habitat in England of the common seal, which despite its name is not numerous. Any major works in the estuary would change the sandbanks which the seals use, but this would be unlikely to affect the numbers of seals in the long term.

40. The construction of any storage scheme would be detrimental to nature conservation, but some of the schemes would be less so than others. If a small portion of the Wash is to be developed an area near the mouth of the Great Ouse would be the least damaging. The loss in salt and brackish water habitats could be offset to some degree by the creation of new freshwater habitats which could become attractively colonised by different flora and fauna. Experience in the Netherlands has shown that an attractive new marine margin environment may be built up by tidal action on the seaward side of a barrage.

Amenity and Recreation

41. The Wash area as a whole does not attract large numbers of holiday-makers and day visitors, but it is not without visual appeal, and has some well-established holiday centres like Hunstanton. With sensitive design, bunded reservoirs or barrages might be given an acceptable appearance, but possibly bunded reservoirs would present the greater problem.

42. There is relatively little sailing or cruising in the Wash, probably because of the tidal peculiarities which make it suitable only for experienced sailors, the difficulties of access over the extensive mudflats on the southern and western shores, and the lack of any water safety organisation operating in the area. Any of the possible forms of storage would provide a safer sailing area.

43. Any future more detailed examination of the possibilities of storing fresh water in the Wash should include studies of the implications for the ecology, neighbouring beaches and coastline, wildlife, landscape, and recreation potential of the area. With all the reservations expressed, the consensus of opinion is that most damage to these factors would occur with the complete closure of the Wash and correspondingly less for a barrage from Snettisham to Butterwick. Of the corner barrages, that across the mouth of the Great Ouse would cause the least disturbance. Bunded reservoirs of more limited area would have correspondingly smaller effects.

Fisheries

44. The Wash fisheries and associated industries make a valuable contribution to the local economy. Boston, Fosdyke, Sutton Bridge and King's Lynn are minor fishing ports, Boston and King's Lynn being the biggest. Catches of shrimps, cockles, mussels and sprats had a value of about £200,000 in 1968. The shrimp and cockle catches represent more than 40% of the total for the United Kingdom, and processing of these catches is an important local industry.

45. Quantities of mullet, sea trout, flounder, sole and roker (a species of thornback ray) are caught, but white fish is not important in the economics of Wash fisheries. There is some evidence that the innermost shallow water areas along the north coast and southwards as far as King's Lynn provide nursery grounds for North Sea flatfish, notably plaice, turbot and brill.

46. The effect of any water storage scheme on the existing fisheries will need further investigation. Some losses seem to be unavoidable, but may be at least partially offset by a limited potential in the storage schemes for fish farming. In particular, eel production may be feasible either in the reservoirs or in segregated areas of them, and some coarse fish production on a commercial scale may also be feasible. The capital cost for eel and coarse fish cultivation is not thought to be substantial.

Land Reclamation

47. Reclamation of land from the Wash for agriculture has gone on for at least 500 years. The rate of reclamation has averaged very roughly 100 km^2 (25,000 acres) per century, and reclamation is likely to continue for some time if there is no development in the estuary. The Crown Estate Commissioners and one of the County Councils bordering the Wash are concerned that a water conservation scheme might limit the potential for land reclamation.

48. A water conservation scheme would not necessarily inhibit all further reclamation of land. A barrage would end the tidal circulation of silt, and hence stop natural accretion, on its landward side, but some accretion might occur to seawards. The area occupied by bunded reservoirs would obviously not be available for reclamation, but increased silting might occur in their vicinity, and particularly between them and the present shore line.

49. Apart from gains to agricultural land, other aspects of land reclamation have been noted. The construction of any storage scheme would be rapid when compared with the present rate of land reclamation; many wildlife habitats would be lost, and replacements would not have time to become established. On ecological grounds, the gradual reclamation of land is to be preferred since wildlife is more likely to adjust to this than to rapid environmental changes.

50. The construction of storage works in the Wash might provide opportunities for the use of a part of its area for water or land based recreation and for nature conservation, and the economic possibilities of afforestation in suitably landscaped areas to which the public would have access might be worthy of investigation.

Land Drainage

51. Any water conservation scheme would affect the land drainage of areas adjacent to the Wash by changing tidal levels, the movement of sand and silt, and consequently channel discharge characteristics.

52. Bunded reservoirs would be unlikely to affect river outfalls (and hence the existing land drainage regime) at some distance from them. Their effects on adjacent rivers, particularly in their tidal reaches, are less certain. It is possible that, because tidal currents and residual freshwater flows would be smaller, siltation might occur in the tidal reaches and impede flood flows. On the other hand, high tides might become slightly higher but of shorter duration, with longer periods of low water; in that event, drainage systems discharging to the tidal reaches might discharge more efficiently than at present.

Sea Defence

53. The effect on the existing arrangements for sea defence will obviously depend on the conservation scheme adopted. Generally, the present (fairly small) overall expenditure on sea defence might be expected to be reduced, because of the reduced length of coastline involved. However, the Consulting Engineers consider that a major barrage would increase sea defence costs. The effects, either way, would not be significant in the general balance of costs and benefits.

Existing Navigation and Port Facilities

54. The three chief ports of the Wash are King's Lynn, Boston and Wisbech. These ports provide useful facilities for sea traffic with Europe, but most trade with the Continent is conducted through other east coast ports. Currently the Wash ports handle some 1,500,000 tons of cargo annually, of which 80% are imports. But they have some disadvantages: they are accessible only at certain states of the tide; their approach channels are narrow and tortuous; and their road and rail links with the rest of the country are not good. We have been left in no doubt that any scheme which might cause the ports to decline would be vigorously opposed locally.

55. The Secretary of State for Economic Affairs, in a statement in July 1969*, named the Wash as one of eleven areas under consideration for development as maritime industrial development areas (MIDA), ie areas of land suitable for industrial development which have easy deep water access for big ships. The likelihood of a development of this kind in the Wash cannot be forecast at present.

Transport and Communications

56. The trunk roads A16, A17 and A47, each connecting with the A1, link the Wash area to the national road network. Improvement to the A47 and A17, including a major by-pass for King's Lynn, will provide good routes for the major east-west traffic movement. The A16 is also being steadily improved, as are the principal roads skirting the Wash.

57. The area round the Wash is sparsely populated, and the local towns are small. A road built along the line of the embankment of any of the proposed conservation schemes would have little value in relation to its cost. It would lack links with the existing road network and need considerable improvements at either end. The improvement schemes on the A17 and A47, on the other hand, will when completed offer a fast and convenient route for long distance traffic and, together with improvements to the other existing roads, serve the needs of the area in the light of existing and planned development.

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* *Official Report, House of Commons, Thursday 17th July 1969, cols 164-5*

INVESTIGATION AND CONSTRUCTION: POSSIBLE SEQUENCES

A Feasibility Study

58. The Consulting Engineers' Report indicates that there is unlikely to be any insuperable technical difficulty in constructing either bunded reservoir storage in the Wash or a main estuarial barrage on a line from Snettisham to Butterwick Low. Further investigations are required to identify the engineering problems in more detail, to refine estimates of costs, and to assess the effects of the proposals on other interests. In any civil engineering works on this scale, extensive site surveys and exploration, and the study of available materials and construction methods, are required before final designs can be determined. To construct freshwater reservoirs in the Wash involves additional problems of the closure of embankments against the tide, the removal of sea water and salt from the enclosed bed of the estuary, and the effects of tides and waves on the completed structures. The consequential problems are the maintenance of drainage and navigation and the effects of the schemes on ecology, amenity and other interests.

59. The contents of the feasibility study may be considered in three general groups: engineering; the natural environment; and the economic environment.

Engineering

60. In Chapter 11 of their Report the Consulting Engineers describe in detail the surveys and investigations necessary to establish engineering feasibility. The main items are:-

(i) Topographic and hydrographic surveys.

(ii) Geotechnical investigations in the estuary, at quarry sites and on the routes of proposed aqueducts.

(iii) Hydraulic model testing.

(iv) Trial banks and site structures.

Under item (iv) the Consulting Engineers propose the construction of trial banks and other works to provide data on the suitability of materials, construction

plant and embankment design, and to enable full-scale seepage and salinity tests to be carried out. It is our view, however, that trial banks and site structures are better regarded as a preliminary to the work of construction than as part of the feasibility study. We think that a decision on trial banks should therefore be deferred until the decision whether to construct a Stage I reservoir is taken.

61. The Consulting Engineers also point out that if storage were to be constructed in stages, there would be a continuing need for investigations for the detailed design of each stage and to bring up to date the information obtained from the feasibility study. These investigations would be part of a programme of development and not of the feasibility study as such. Following Dutch practice, a model would be retained throughout the whole of the construction period, and there may be a case for establishing special facilities for the model from the outset.

The Natural Environment

62. The ecology of the reservoirs and fringe areas and of the new land and water areas which might be created, and the overall gains and losses to sea and inland fisheries, vegetation and wild life habitats, will require further detailed study under the general guidance of the Natural Environment Research Council. There should be no difficulty in planning these studies to run concurrently with the engineering studies.

The Economic Environment

63. The preliminary studies summarised in Chapter 3 deal with the possible impact of storing water in the Wash on road traffic; shipping access and port facilities; land reclamation for agriculture; recreational facilities; and the general economy of the surrounding area. Their broad conclusion is that these considerations have little economic weight in comparison with the costs and problems of the storage project. But detailed investigations should be pursued in parallel with the engineering studies.

Interdependence of Specialist Studies

64. If water conservation is to be successfully integrated with the requirements of the natural and economic environment, there must be full communication between the engineers, scientists, planners and economists concerned throughout all stages of the study.

Possible Sequences

65. The Consulting Engineers have considered how long after the start of a feasibility study water could first be available from storage in the Wash. They estimate that the feasibility study itself would take six years, or seven if a shore-to-shore barrage were included; this period is determined by the hydraulic model tests required. They allow a further four years for "promotion", ie decision-making, obtaining of powers etc; and another eight years for design and construction. Feasibility study, promotion, design and construction would thus take 18 years, if the usual practice were adopted whereby each of these stages is separate. In other words, if a feasibility study were authorised to start in 1971, water would first become available in 1989. This sequence is illustrated as "Programme B" in Fig.1, which is reproduced from the Consulting Engineers' Report.

66. The Consulting Engineers recommend an alternative sequence in which the stages of investigation, promotion and design are overlapped and a decision whether to construct a first bunded reservoir could be taken after two years. In this way the period from the start of the feasibility study to the first availability of water would be shortened from 18 to 9 years; in other words, if the feasibility study is started in 1971, water would first be available in 1980. This sequence is illustrated as "Programme A" in Fig. 1.

67. We have reservations about both these possible sequences. We consider that if storage in the Wash is to make a contribution to resources in the Central Area, it will be required between 1981 and 1985, assuming that the Empingham scheme is built and that the ground-water schemes are reasonably successful. Programme B, assuming a start in 1971, could not produce water before 1989; and it has the further disadvantage that a decision whether to construct a first stage of storage could not be taken before 1977 at the earliest. Programme A does not make enough allowance for the time which would necessarily be taken in reaching a decision whether to construct a first stage, and we consider that the total length of nine years is a little optimistic.

68. We consider that a practicable compromise between these two programmes could be achieved if the construction of a first bunded reservoir were regarded as a separate question from the construction of a full series of reservoirs. This would require readiness to take a decision on the first bunded reservoir without

commitment to later ones. In this way, if a feasibility study were authorised to start in 1971, a decision whether to construct a first bunded reservoir could be taken by 1974, and the reservoir could be completed by about 1983-1984.

69. The feasibility study itself, however, is an indivisible whole, because of the importance of the hydraulic model tests. It would not be practicable to separate the study into stages in step with stages of construction.

Costs of Investigation

70. The Consulting Engineers estimate the costs of a feasibility study, including tests on the line of a shore-to-shore barrage, trial banks and site structures, at £2.5 m at 1969 prices. We consider that, since the shore-to-shore barrage is not well suited for water storage and almost certainly unnecessary otherwise, it should be omitted from the feasibility study; and that the trial banks and site structures should be deferred until the decision is taken whether to construct a first bunded reservoir. The shore-to-shore barrage tests, trial banks and site structures, together with detailed site investigations for a first reservoir, account for some £1.5 m out of the total of £2.5 m, leaving £1.0 m. The environmental and other ancillary studies required would probably cost about a further £0.1 m, making £1.1 m altogether. This expenditure would be distributed over the period of the feasibility study approximately as follows:-

Year	1	2	3	4	5	6	Total
£ x 000	280	320	220	130	80	70	1,100

71. We recommend that a feasibility study on these lines should be authorised to begin early in 1971 and to be completed in 1977-1978 at a cost of £1.1 m at 1969 prices. The study should be so designed as to enable a decision to be taken in 1973-1974 whether to construct a first bunded reservoir in time to produce water in the early 1980's.

Administrative Machinery

72. Construction and operation of storage works in the Wash would be an administrative task of considerable size and complexity. Early consideration should be given, simultaneously with the feasibility study, to the question of appropriate administrative machinery to implement any decision to construct a first bunded reservoir.

CHAPTER 5

USING THE WATER: POSSIBLE PROGRAMMES

73. In order to examine how water from storage in the Wash might contribute to meeting needs in the Central Area of South East England, we have considered seven possible programmes of development in which this and other sources are deployed in different ways. These programmes are described in this chapter and illustrated in Diagrams 0-6 at the end of the Report.

74. We have revised our estimates of future deficiencies in the Central Area for public water supply, industry and agriculture, allowing for the re-use of water, as follows:

Central Area Deficiency: Revised Estimates

Year	1971	1981	2001
000 m^3/d	385	1 270	3 040
mgd	85	280	670

These estimated deficiencies include the needs now being met from Grafham Water, since the full yield of the reservoir could probably be used more advantageously in future by re-allocating it.

75. When the Ely Ouse, Grafham and Empingham schemes are completed, and if ground-water resources can be developed to the full yields of 1 320 000 m^3/d (290 mgd) envisaged in our Report of 1966, the needs of the Central Area will be met until the late 1980's. But it is by no means certain that ground-water resources can be developed to this extent; and a major new source may well be required for the Central Area in the early 1980's.

76. We have divided the Central Area into twelve demand districts. The needs of each district are represented by the sum of the needs within it at a notional delivery point at the centre of gravity of demand, as shown on Map 2. The alternative programmes incorporate selected source works, regional delivery networks and treatment works, to meet the predicted growth of need at the notional destinations. The costs of constructing, maintaining and operating storage works, pumping stations, strategic aqueducts, treatment works and terminal storage from 1971 to the terminal date - normally 2001 - are incorporated in the analysis. Overheads on the works are included but not the costs of distribution beyond the notional destinations. The costs of maintenance and

operation - including renewals of assets - have then been projected to perpetuity and the total expenditure discounted to the year 1970 at the rate of 10%.

77. The pattern of development before 1981 is determined by the inland sources available and is essentially the same for any subsequent strategy. All the programmes therefore follow a common pattern up to 1981, as shown in Diagram 0. This may be summarised as follows:

TABLE 1 DEVELOPMENTS BEFORE 1981

	Yield			
	000 m^3/d		mgd	
Authorised and existing sources				
Local sources in Essex (not shown in diagrams)	45		10	
Ely Ouse Scheme	115		25	
Grafham Water full development	295		65	
Empingham	225		50	
Total		680		150
Ground-water development				
Thames basin	405		90	
Great Ouse basin	180		40	
Total		585		130
Combined total		1 270		280
(Nearest 10 000 m^3/d (2 mgd))				

78. We estimate that a further 1 765 000 m^3/d (390 mgd) will be needed for the Central Area between 1981 and 2001. Of this, 725 000 m^3/d (160 mgd) might come from further development of the two ground-water schemes. But if this proved impossible, then Central Area inland sources alone would not suffice, and must be supplemented from the Wash, from desalination or from imports.

Programme No. 1: Inland Sources Only

79. This programme would meet the needs of the Central Area by developing the inland sources which we recommended in our Report of 1966 for investigation. In addition to the sources listed in Table 1, it would require further development

of the ground-water schemes to give an additional 725 000 m^3/d (160 mgd) making 1 320 000 m^3/d (290 mgd) altogether, and the construction of five major reservoirs. It may be summarised thus:

Programme No. 1

	000 m^3/d	mgd	Year entering service
Existing and authorised sources	680	150	Before 1976
Ground water	1 315	290	1971-1991
New reservoirs	1 045	230	1989-2001
Total	3 040	670	

The sequence of major reservoirs required might be:-

Reservoir	Yield		Date required in service
	000 m^3/d	mgd	
Waddesdon	410	90	1989
Cobbins Brook	180	40	1994
Abbotsley (or Great Bradley)	90	20	1996
Manton	140	30	1998
Whitchurch	225	50	1999
Total	1 045	230	

Programme No. 2: Maximum Wash Contribution

80. This programme would introduce water from Wash storage in 1981. This would be necessary if the ground-water schemes were not capable of development beyond a yield of 590 000 m^3/d (130 mgd) in 1981, if further reservoirs were not to be constructed in the Central Area and if water were not imported from other areas. The contribution from Wash storage would reach 1 765 000 m^3/d (390 mgd) by 2001. However, this programme would require reservoirs to be built in the Wash almost as rapidly as in the Consulting Engineers' Programme A (paragraph 66), about which we have expressed our reservations. It may be summarised thus:

Programme No. 2

	000 m^3/d	mgd	Year entering service
Existing and authorised sources	680	150	Before 1976
Ground water	590	130	1971-1981
Wash storage	1 765	390	1981-2001

Programme No. 3: Ground Water and Wash Storage

81. This programme would require maximum development of the ground-water schemes to 132 000 m^3/d (290 mgd) and development of storage in the Wash to provide 1 040 000 m^3/d (230 mgd) starting in 1989. Like programme No. 2, it would not require new inland surface reservoirs after 1981. It provides a direct comparison between the costs of using Wash storage and those of using the five new major reservoirs listed in programme No. 1. It may be summarised thus:

Programme No. 3

	000 m^3/d	mgd	Year entering service
Existing and authorised sources	680	150	Before 1976
Ground water	1 315	290	1971-1991
Wash storage	1 040	230	1989-2001

Programme No. 4: Ground Water, Wash Storage, Reservoirs

82. This programme combines a limited amount of Wash storage with two new inland reservoirs, and is in two versions giving different sequences of development. The Wash storage precedes the reservoirs in version 4(a) and follows them in version 4(b); the yields, and the pattern of development at the year 2001, are the same in both. The programme may be summarised thus:

Programme No. 4 (a)

	000 m^3/d	mgd	Year entering service
Existing and authorised sources	680	150	Before 1976
Ground water	1 315	290	1971-1991
Wash storage	455	100	1989-1995
New reservoirs	590	130	1996-2001

Programme No. 4(b)

	000 m^3/d	mgd	Year entering service
Existing and authorised sources	680	150	Before 1976
Ground water	1 315	290	1971-1991
New reservoirs	590	130	1989-1996
Wash storage	455	100	1996-2001

The new reservoirs included in this programme are:

Programme No. 4

Reservoir	Yield		Dates required in service	
	000 m^3/d	mgd	4(a)	4(b)
Waddesdon	410	90	1996	1989
Cobbins Brook	180	40	1999	1994

Programme 4(a) postulates the completion of a Stage I development in the Wash by 1989 without commitment to further stages, and 4(b) the completion of a Stage I development by 1996.

Programme No. 5: Ground Water and Desalination

83. This programme would substitute desalted sea water for the contribution made by Wash storage in programme No. 3, to meet the needs of those areas - mainly in Essex and East Anglia - which could most readily be supplied from the sea. It envisages a contribution of 1 045 000 m^3/d (230 mgd) from desalination, starting in 1989; and like programme No. 3, it would not require further new reservoirs after 1981. It may be summarised thus:

Programme No. 5

	000 m^3/d	mgd	Year entering service
Existing and authorised sources	680	150	Before 1976
Ground water	1 315	290	1971-1991
Desalination	1 040	230	1989-2001

Programme No. 6: Ground Water, Desalination, Reservoirs

84. This programme would substitute desalted sea water for the Wash storage contribution in programme No. 4(b) and combine it with the same two reservoirs - Waddesdon and Cobbins Brook. It may be summarised thus:

Programme No. 6

	000 m^3/d	mgd	Year entering service
Existing and authorised sources	680	150	Before 1976
Ground water	1 315	290	1971-1991
New reservoirs	590	130	1989-1996
Desalination	450	100	1996-2001

Costs

85. The basis on which the costs of these programmes are calculated is given in paragraph 76. We emphasise that the costs can be only approximate: they constitute a broad basis for comparison rather than actual expenditures. The programmes fall into two groups as regards costs: on the one hand Nos. 1, 3, 4(a), 4(b) and 6; and on the other Nos. 2 and 5. Within each group the differences in estimated costs between programmes are so small that it would give a false impression of precision to set them out separately. We therefore give a typical cost for each group.

Typical Programme Costs 1971 – 2001
(£ millions)

	Programmes	
	1, 3, 4(a) 4(b), 6	2, 5
Total Capital Investment	280	310
Cumulative Operating Costs	170	220
Total:	450	530
Equivalent Present Value (1970) (at 10% pa discount)	120	140

86. The estimated costs of storage works in the Wash are broadly comparable with the costs of inland storage works. The costs of delivering to demand centres water from Wash storage and from inland storage are also broadly comparable for yields up to about 1 040 000 m^3/d (230 mgd) (programme No. 3). But for larger amounts of water from the Wash or from desalination plants delivered over the Central Area, the costs of delivery become proportionately much higher; it is these costs which account for the differences between the two groups of approximately £80 million in conventional terms and £20 million in discounted terms.

87. The costs of the desalination component in programmes Nos. 5 and 6 are based on the distillation costs given in our Report on Desalination in England and Wales (1969). By the time the desalination plants envisaged in these programmes would need to be installed, advances in the technology will probably have affected the cost comparisons significantly.

88. The programmes and their typical costs are set out in summary form in Table 2 at the end of this chapter.

Summary

89. It may well prove possible to meet the needs of the north eastern part of the Central Area from the early 1980's to the turn of the century (up to something like 9 000 000 m^3/d (200 mgd)) from storage in the Wash or from desalination plants, or from a combination of the two, at costs broadly comparable with those of inland reservoir and ground-water sources; but to supply the whole of the Central Area in these ways would involve considerable extra costs, perhaps up to £80 million, or £20 million in discounted terms.

TABLE 2. SUMMARY OF PROGRAMMES

Programme No.	Description	000 m^3/d*	mgd	Period entering service	Typical total cost (£ millions)
1	Existing and authorised sources	680	150	Before 1976	450
	Ground water	1 315	290	1971-1991	
	New reservoirs	1 045	230	1989-2001	
2	Existing and authorised sources	680	150	Before 1976	530
	Ground water	590	130	1971-1981	
	Wash	1 765	390	1981-2001	
3	Existing and authorised sources	680	150	Before 1976	450
	Ground water	1 315	290	1971-1991	
	Wash	1 040	230	1989-2001	
4(a)	Existing and authorised sources	680	150	Before 1976	450
	Ground water	1 315	290	1971-1991	
	Wash	455	100	1989-1995	
	New reservoirs	590	130	1996-2001	
4(b)	Existing and authorised sources	680	150	Before 1976	450
	Ground water	1 315	290	1971-1991	
	New reservoirs	590	130	1989-1996	
	Wash	455	100	1996-2001	
5	Existing and authorised sources	680	150	Before 1976	530
	Ground water	1 315	290	1971-1991	
	Desalination	1 040	230	1989-2001	
6	Existing and authorised sources	680	150	Before 1976	450
	Ground water	1 315	290	1971-1991	
	New reservoirs	590	130	1989-1996	
	Desalination	450	100	1996-2001	

**Metric equivalents rounded to nearest 5 000 m^3/d.*

CHAPTER 6

SUMMARY AND RECOMMENDATIONS

The Background

90. Any strategy for developing water resources to meet needs in the Central Area of South East England up to the end of this century must include some or all of the following options: (i) surface reservoirs; (ii) ground water; (iii) desalination; (iv) estuary storage in the Wash. (paragraphs 1-2)

91. The best combination of these options can be chosen only in the light of detailed physical investigations. These are in hand for surface reservoirs, ground water and desalination, none of which is free from either objection or uncertainty. Physical investigation of estuary storage remains to be undertaken. (paragraphs 3-6)

The Results of the Desk Study

92. Fresh water could best be stored in the Wash in three or four bunded reservoirs just off-shore. These could be built one at a time. (paragraph 16)

93. A barrage to enclose the whole of the Wash could not be built with existing technology. A barrage to enclose approximately the inner half of the Wash would be technically possible, but it would not be an acceptable alternative to bunded reservoirs and would be almost certainly unnecessary in addition to them. (paragraphs 16-18)

94. A first (Stage I) bunded reservoir, at an estimated cost of £25 million, could yield up to 450 000 m^3/d (100 mgd), depending on the requirements for residual flow in the Great Ouse. (paragraphs 31-34)

95. Bunded reservoirs in the Wash would be unlikely to do serious or lasting damage to the environment. (Chapter 3)

96. A feasibility study, ie the physical and other investigations required, could be completed in 6-7 years after authorisation at a cost of £1.1 million; a decision could be taken after 2-3 years of the study whether to construct a Stage I reservoir. (paragraphs 65-71)

97. Construction of trial banks and site structures should be deferred until the decision whether to construct a Stage I reservoir is taken. (paragraph 60)

98. If a feasibility study is started in 1971 and confirms the findings of the desk study, a Stage I reservoir could be built in time to produce water in the early 1980's. (paragraph 68)

Using the Water

99. The Central Area will require a major new source in the 1980's; the actual date will depend upon how the ground-water schemes turn out. (paragraph 75)

100. It may well prove possible to supply the needs of the north eastern part of the Central Area from the early 1980's to the turn of the century (up to something like 9 000 000 m^3/d (200 mgd)) from storage in the Wash or from desalination plants, or from a combination of the two, at costs broadly comparable with those of inland reservoir and ground-water sources; but to supply the whole of the Central Area in these ways would involve considerable extra costs, perhaps up to £80 million, or £20 million in discounted terms. (Chapter 5)

Administrative Machinery

101. Construction and operation of storage works in the Wash would require appropriate administrative machinery. (paragraph 72)

Recommendations

102. We therefore recommend that

(i) a feasibility study of the possibilities of freshwater storage in the Wash should be authorised forthwith, to begin in 1971 and to be completed in 1977/78 at a cost of £1.1 million;

(ii) the study should be so designed as to enable a decision to be taken in 1973/74 whether to construct a first (Stage I) bunded reservoir in the Wash to yield up to 450 000 m^3/d (100 mgd) by the early 1980's;

(iii) a decision whether to construct trial banks and site structures should be deferred until the decision is taken whether to construct a Stage I reservoir;

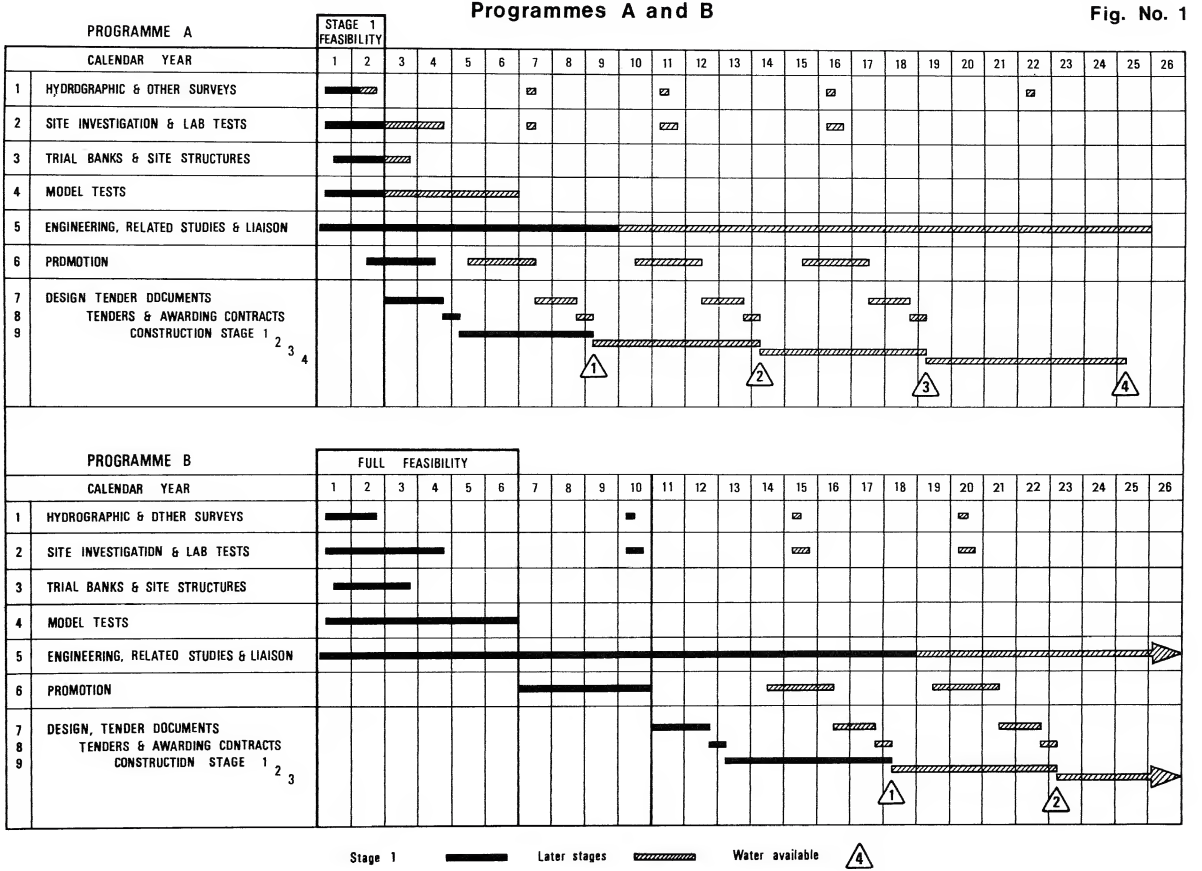
(iv) decisions whether to construct further stages of storage in the Wash should be deferred until the feasibility study is complete and until more detailed information is available about the ultimate yield of the ground-water schemes and about the costs of desalination processes;

(v) early consideration should be given to the form of administrative machinery which would be required to implement a decision to construct and operate storage works in the Wash.

POSSIBLE PROGRAMMES OF DEVELOPMENT SUGGESTED BY CONSULTING ENGINEERS

Programmes A and B

Fig. No. 1



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WATER RESOURCES BOARD

THE WASH: ESTUARY STORAGE

REPORT ON THE DESK STUDY

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